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ESTABLISHING EQUIVALENCE RELATIONS USING A RESPONDENT-TYPE TRAINING PROCEDURE

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During three experiments, 35 human, adult subjects across seven experimental conditions (5 subjects in each condition) were exposed to a respondent-type training procedure in which arbitrary stimuli (i.e., nonsense syllables) were presented, one at a time, on a computer screen. In Condition 1, Experiment 1, instructions informed the subjects that the material to be presented during the first stage of the experiment (i.e., the respondent-type training procedure) was related to the second stage (i.e., the equivalence test). Nine nonsense syllables were presented to the subjects in the form of six stimulus pairs: A1→B1, B1→C1, A2→B2, B2→C2, A3→B3, B3→C3. The first stimulus of each pair was presented for 1 s (e.g., A1), the computer screen was cleared for 0.5 s (the within-pair-delay) and the second stimulus in the pair (i.e., B1) was presented for 1 s. The screen cleared for 3 s (i.e., the between-pair-delay) before the next stimulus pair was presented. All six stimulus pairs were presented 10 times in a quasi-random order across 60 trials. Subjects were presented with a standard matching-to-sample equivalence test that examined the six symmetry relations (i.e., B1-A1, B2-A2, B3-A3, C1-B1, C2-B2, C3-B3) and the three equivalence relations (i.e., C1-A1, C2-A2, C3-A3). All five subjects demonstrated equivalence responding after two, three, or four exposures to the training *and* testing. The remaining six conditions, across the three experiments, showed that the effectiveness of the respondent-type training procedure in producing equivalence responding was dependent upon (a) the presence of longer between-pair-delays relative to the within-pair-delays and (b) the sequence in which the stimulus pairs were presented.

When verbally-able humans are taught a series of related conditional discriminations using a matching-to-sample procedure, the

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stimuli that enter into these discriminations often become related to each other in novel ways not explicitly taught during training. In a typical experiment, for example, selecting stimulus B in the presence of stimulus A is reinforced, and selecting stimulus C in the presence of B is reinforced (i.e., see A pick B, and see B pick C). During a subsequent test, subjects may select A in the presence of B, B in the presence of C (B-A and C-B are symmetry relations), and C in the presence of A (C-A is a combined symmetry and transitivity, or equivalence relation). If these performances are produced in the absence of differential reinforcement, they are normally accepted as evidence that the A, B, and C stimuli participate in an equivalence relation (see Barnes, 1994; Barnes & Holmes, 1991; Fields & Verhave, 1987; Hayes, S. C., 1991; Sidman, 1990).

The training procedures employed in the investigation of stimulus equivalence typically incorporate some form of operant requirement. For example, simple discriminations (e.g., deRose, McIlvane, Dube, Galpin, & Stoddard, 1988), conditional discriminations (e.g., Barnes, McCullagh, & Keenan, 1990; Devany, Hayes, S. C., & Nelson, 1986; Sidman, 1971; Sidman & Tailby, 1982; Smeets, Schenk, & Barnes, 1995), and differentially reinforced sequence responses (Green, Stromer, & Mackay, 1993) have all been used in equivalence research. Although a number of recent equivalence studies have also employed multi-element or compound stimuli in training and testing for equivalence relations (see Hegarty, Barnes, & Smeets, 1995; Markham & Dougher, 1993; Smeets et al., 1995; Stromer & Mackay, 1993; Stromer, McIlvane, & Serna, 1993), all of these experiments employed some form of operant training (i.e., presenting differential consequences contingent upon certain responses) before testing for equivalence relations.

To date, no published experimental study has attempted to generate equivalence responding using a respondent, rather than an operant, training procedure. Consequently, one important step in identifying the necessary and/or sufficient conditions for producing equivalence responding, would be to determine whether stimulus equivalence emerges when a respondent-type training procedure is used. Consider, for example, one such procedure in which an arbitrary stimulus A reliably predicts the appearance of a second arbitrary stimulus B (i.e., A→B). Following sufficient exposure to this stimulus pairing, would a subject reliably choose stimulus A in the presence of B on a matching-to-sample task? In effect, having been exposed to A→B respondent-type training, would the subject respond in accordance with the B-A symmetry relation? Furthermore, if stimulus A always precedes B and B always precedes C in a respondent-type training procedure (A→B→C), would a subject reliably choose A in the presence of C on a subsequent matching-to-sample task? In other words, having been exposed to A→B→C respondent-type training, would the subject respond in accordance with the C-A equivalence relation? Condition 1 (Experiment 1) aimed to discover whether respondent-type[1] training would establish symmetry and equivalence responding in adult humans. The remaining conditions across the three experiments addressed a number of related issues.

In Condition 1 (Experiment 1) 5 subjects were provided with detailed instructions that specified that the first part of the experiment (the respondent training) was related to the second part (the equivalence test). The 5 subjects were exposed to a respondent training procedure in which six stimulus pairs (A1→B1, B1→C1, A2→B2, B2→C2, A3→B3, B3→C3) were presented to the subjects on a computer screen (i.e., no overt observing responses were required). A 0.5-s 'within-pair-delay' separated the presentation of the stimulus pairs (e.g., A1→blank screen for 0.5 s→B1), and a 3-s 'between-pair-delay' separated the presentation of stimuli from separate stimulus pairs (e.g., B1→blank screen for 3 s→B2). At this point in the research program we assumed that the within-pair-delays would have to be discriminably shorter than the between-pair-delays, otherwise subjects would be unable to discriminate six distinct stimulus pairs, and they would therefore fail to respond in accordance with the predicted equivalence relations. Following respondent training subjects were exposed to a standard matching-to-sample procedure that tested for responding in accordance with symmetry relations (i.e., B1-A1, B2-A2, B3-A3, C1-B1, C2-B2, C3-B3) and equivalence relations (C1-B1, C2-B2, C3-B3).

In Condition 2, an additional 5 subjects were exposed to the same procedures, except that minimal instructions were used (i.e., the instructions did *not* specify a relationship between the first and second parts of the experiment). This condition allowed us to assess whether specifying a link between respondent training and equivalence testing, facilitates, suppresses, or does not effect the emergence of equivalence responding (cf. Green, Sigurdardottir, & Saunders, R. R., 1991; Saunders, K. J., Saunders, R. R. Williams, & Spradlin, 1993; Sigurdardottir, Green, & Saunders, R. R., 1990).

Finally, in Condition 3 another 5 subjects were exposed to the same procedures employed in Condition 2 (minimal instructions), except that the 3-s between-pair-delay was reduced to 0.5 s (i.e., all stimuli were separated by 0.5 s). This final condition allowed us to test our assumption that shorter within-pair-delays, relative to between-pair-delays, were required for equivalence responding to emerge.

In the interests of clarity each of the remaining two experiments will be introduced separately.

[1]We have included the suffix "type" to indicate that the respondent training procedure described in this paper departs somewhat from traditional respondent conditioning experiments. For example, the complete respondent-type training procedure (described in the next section) presents nine conditional stimuli (i.e., nonsense syllables) in various sequences, whereas a typical respondent conditioning experiment presents one or two conditional stimuli and an unconditional stimulus. For ease of communication, however, the suffix, "type" will not be used in the remaining text.

General Method

Subjects

Thirty five students, 20 female and 15 male, of University College Cork served as subjects. Their ages ranged from 18 to 25 years. All participants were recruited through personal contacts and faculty board advertisements and were randomly assigned to one of the seven experimental conditions (i.e., five in each condition), across three separate experiments. All subjects were experimentally naive and were non-psychology majors. Sessions were arranged so that participants would not meet each other in the vicinity of the laboratory, and all were instructed not to inform or discuss their participation in the study with anyone. If a subject did not complete the experiment during the first visit to the laboratory, he or she was asked to return on a subsequent day (usually the next day). In fact, only two subjects (6 and 14) had to attend more than once to complete their participation in the study.

Apparatus

Each subject was seated in a small experimental room, with an Apple Macintosh SE microcomputer, which displayed black characters on a white background. Stimulus presentation and the recording of responses were controlled by the computer which was programmed in BBC BASIC. The Z, V, and M keys were marked with white paper dots to designate them as response keys. Nine nonsense syllables (CUG, ZID, VEK, YIM, DAX, PAF, ROG, MAU, JOM; see Barnes & Keenan, 1993) were randomly assigned to their respective roles as sample and comparison stimuli for each subject in the study.

Experiment 1

Procedure

Condition 1

In Condition 1 (detailed instructions/random sequence of stimulus pairs/3-s between-pair-delays), participants were seated in the experimental room and the following instructions were presented on the computer screen:

> During the first stage of this experiment you will be presented with nonsense syllables on the computer screen. You should pay close attention to this first stage because it is relevant to the second stage of the experiment. Press the space-bar twice when you are ready to begin.

Each session was divided into two stages: (a) respondent training and (b) equivalence testing.

Respondent training. During the respondent training nine nonsense syllables were presented to the subjects in the form of six

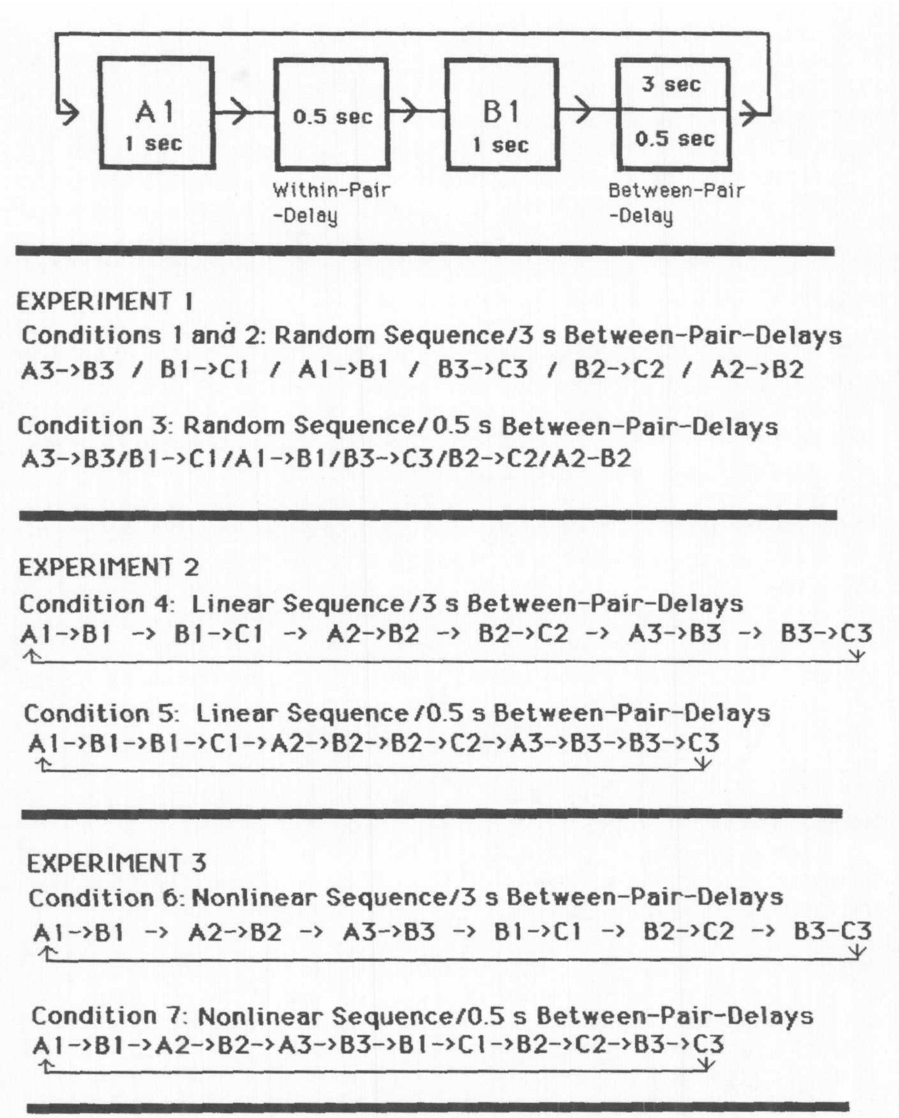

Figure 1. Diagrammatic representation of the respondent training procedure (top panel). Lower panels represent the sequences in which the stimulus pairs were presented across the seven conditions in the three experiments.

stimulus pairs (see Figure 1, panel 2). The stimulus pairs were designated A1→B1, B1→C1, A2→B2, B2→C2, A3→B3, B3→C3. Each stimulus pair was presented in the following sequence (see Figure 1, panel 1). The first stimulus of each pair was presented for 1 s (e.g., A1), and the computer screen was then cleared for 0.5 s (i.e., the within-pair-delay). The second stimulus in the pair (i.e., B1 always followed A1) was presented for 1 s and the screen was then cleared for 3 s (i.e., the between-pair-delay). Following the 3-s between-pair-delay the next stimulus pair was presented (e.g., B3→C3). All six stimulus pairs were presented in this fashion, in a quasi-random order for 60 trials, the only constraint being that each stimulus pair was presented once in each successive block of 6 trials (i.e., each stimulus pair was presented 10 times). When all 60 trials had been presented, the screen went blank for 5 s; the equivalence testing instructions then appeared immediately on the screen (see next section).

Equivalence testing. During this stage subjects were presented with a standard, matching-to-sample equivalence test that examined the six symmetry relations (B1-A1, B2-A2, B3-A3, C1-B1, C2-B2, C3-B3) and the three equivalence relations (C1-A1, C2-A2, C3-A3). The test consisted of the nine matching-to-sample tasks shown in Figure 2. The sample was always presented in the center, top half of the computer screen (5 cm from the upper edge). The three comparison stimuli appeared 1.5 s after the sample stimulus was presented; no overt observing response was required and the sample remained on the screen with the comparisons. The comparisons were presented in a line, 3 cm from the lower edge of the screen. The three comparisons appeared 6 cm to the right, 6 cm to the left, and directly below the sample. The location of the comparisons was counterbalanced across test trials. Participants selected the left, middle, or right comparison by pressing the "Z," "V," or "M" keys, respectively. When a comparison had been selected, the screen cleared immediately and remained blank for 3 s. The next matching-to-sample trial was then presented (i.e., no feedback was presented during the equivalence test).

Before participants were exposed to the equivalence test the following instructions appeared on the computer screen (i.e., 5 s after the last respondent training trial):

> That is the end of the first stage of the experiment. In the next stage you must look at the nonsense syllable at the top, and then choose one of the three nonsense syllables at the bottom by pressing one of the marked keys on the keyboard. To choose the left syllable, press the marked key on the left. To choose the middle syllable, press the marked key in the middle. To choose the right syllable, press the marked key on the right.
> Press the space-bar twice to continue.

The nine matching-to-sample tasks were presented in a quasi-random order for 90 trials, the only constraint being that each of the nine tasks occurred once within each block of 9 trials (i.e., each matching-to-sample task was presented 10 times; 60 symmetry test trials and 30 equivalence test trials). A consistency criterion was used that required each participant must choose the same but *not necessarily correct* comparison at least 9 times out of 10 on each of the 9 tasks (for ease of communication, "correct" will be used to describe responses that are in accordance with the symmetry and equivalence relations). This consistency criterion was used to control for the effects of inadvertent feedback provided by repeated training and testing (see Barnes & Keenan, 1993). If a subject produced an inconsistent performance (i.e., less than 9 out of 10 "same responses" on any of the tasks) he or she was immediately reexposed to the entire experimental procedure (i.e., respondent training and equivalence testing with the same instructions). Because of time constraints, however, Subjects 6 and 14 were allowed a 24-hr break between Exposures 4 and 5. If a subject did not produce a consistent performance by the fourth exposure to the entire experimental sequence, *and* the performance was less than 50% correct (i.e., the subject produced less than 45 correct responses), the performance was classified as inconsistent and the subject's participation in the study was terminated. If, however, a subject produced more than 50% correct responding on a fourth exposure to the equivalence test, additional exposures to the training and testing were provided until he or she either produced less than 50% correct or produced a consistent performance (with three comparison stimuli, 50% correct was 17 points above chance). This criterion thereby ensured that a subject who produced an inconsistent performance, that was considerably higher than chance, would not be prevented from retraining and retesting.

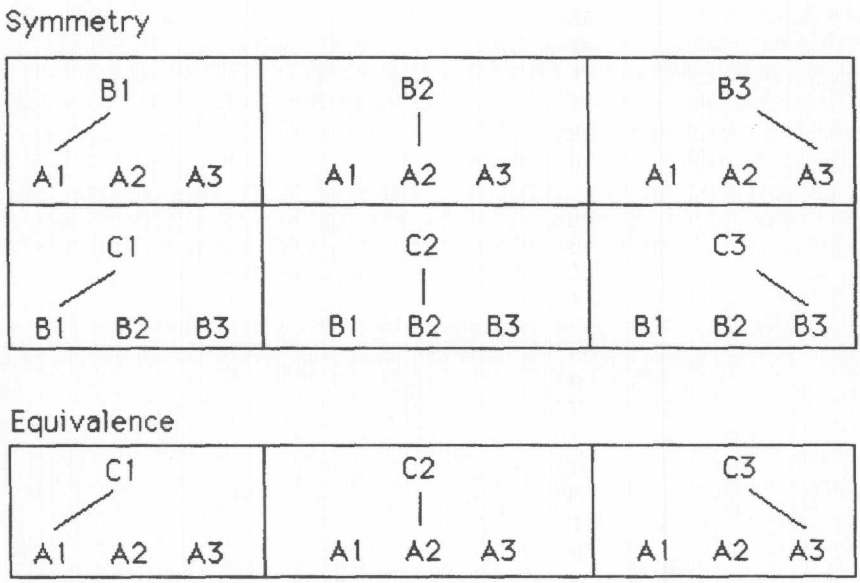

Figure 2. The nine matching-to-sample tasks used to test for symmetry and equivalence relations across each of the three experiments.

Condition 2

Condition 2 (minimal instructions/random sequence of stimulus pairs/3-s between-pair-delays) was identical to Condition 1, except that subjects did not receive the detailed instructions that were given before the respondent training phase of Condition 1 (see Figure 1, panel 2). Instead, the words "Look at the screen" (i.e., minimal instructions) were presented on the computer monitor before the respondent training was initiated. All remaining conditions (3 to 7) across the three experiments also used minimal instructions. Note, however, that the instructions given before the matching-to-sample equivalence test in Condition 1 were also used in this and in all other conditions.

Condition 3

Condition 3 (random sequence of stimulus pairs/0.5-s between-pair-delays) was identical to Condition 2, except that the between-pair-delay of 3 s was reduced to 0.5 s (see Figure 1, panel 3). In effect, there was a 0.5-s delay between the presentation of each stimulus during the respondent training in this condition.

Results and Discussion

The total percentage of correct responses across the 90 test trials (i.e., 60 symmetry and 30 equivalence) for each participant's *final* exposure to the equivalence test is shown in Figure 3. Percentages of correct responses on the 60 symmetry test trials (i.e., B-A and C-B tasks) and on the 30 equivalence test trials (i.e., C-A tasks) for each individual exposure to the equivalence test for Subjects 1 to 15 are presented in Table 1. The reader should note that because there were unequal numbers of symmetry and equivalence test trials (30 and 60, respectively) the total percentage correct for each subject's final exposure shown in Figure 3 is *not* obtained simply by summing the percentages correct for symmetry and for equivalence (shown in the final two columns of Table 1) and then dividing by 2; the percentage values for symmetry, equivalence, and total correct are calculated independently. Subjects in Conditions 1, 2, and 3 (except Subjects 10 and 15) produced almost perfect symmetry and equivalence responding. Subjects 10 and 15 showed a consistently incorrect performance on their third and second exposures respectively, and thus their participation in the study was terminated (see Table 3 for a detailed breakdown of these subjects' final test performances). Six exposures was the maximum required (Subjects 6 and 14) and two was the minimum (Subjects 3, 9, and 15). These data clearly show that the respondent training procedure, combined with either detailed or minimal instructions, can reliably generate equivalence responding in the absence of explicit operant conditioning in the experimental context (because the use of detailed instructions proved to be unnecessary for producing equivalence responding, the remaining experiments reported here utilized only minimal instructions).

Interestingly, in Condition 3, Experiment 1 (random sequence of stimulus pairs/0.5-s between-pair-delays) four participants produced almost perfect equivalence responding. As indicated in the introduction, this outcome was not predicted; it was assumed that reducing the 3-s between-pair-delays to 0.5 s (i.e., to the same value as the within-pair-delays) would prevent subjects from discriminating the six separate stimulus pairs and would thus prevent the formation of equivalence relations. Imagine, for example, that a subject is presented with the following sequence A3→B3/A1→B1 during the first block of six respondent training trials; how might this subject discriminate the A3→B3 pairing from the A1→B1 pairing if each stimulus is separated by the same time interval of 0.5 s (i.e., from the subject's perspective, is B3 paired with A3 or A1)? To answer this question we considered the consistency versus inconsistency of the stimulus pairings across the entire respondent training procedure. In effect, although a subject might not discriminate the A3→B3 pairing from the A1→B1 pairing across the *first* block of six respondent training trials, in the next block of six trials (and every block thereafter) A3→B3 may be followed by any of the other stimulus pairs (e.g., B2→C2), and thus across blocks of six trials A3→B3 and A1→B1 are paired consistently whereas B3→A1 are not. Experiment 2 was designed to examine this issue.

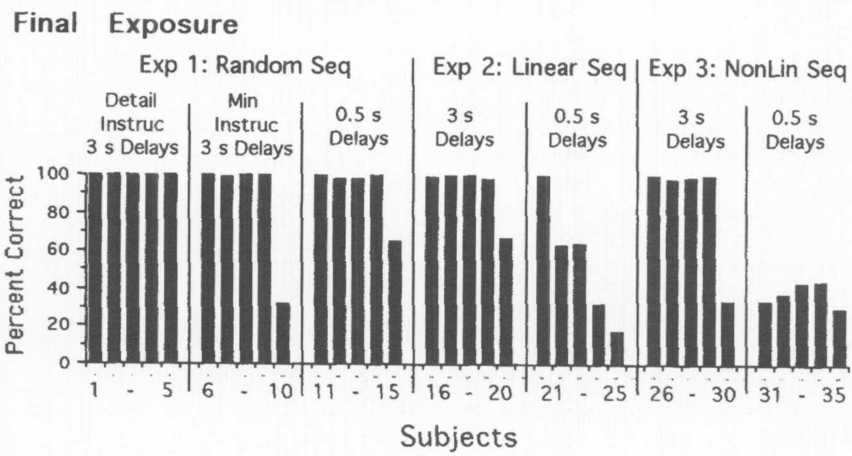

Figure 3. Summary of results for all subjects across the three experiments. Each bar on the graph shows percent correct across the 90 symmetry and equivalence test trials for each subject's *final* exposure to the equivalence test.

Experiment 2

Experiment 2 consisted of Conditions 4 and 5. In both of these conditions the respondent training was modified so that the stimuli were always presented in the *same fixed sequence*, so that subjects could not discriminate the six stimulus pairs based on the consistency versus

Table 1

Percent Correct on 60 Symmetry and 30 Equivalence Test Trials per Exposure

Condition 1
Random Sequence/Detailed Instructions/3-s Between-Pair-Delays
Successive Exposures

	1		2		3		4	
	Sym/	Equiv	Sym/	Equiv	Sym/	Equiv	Sym/	Equiv
Subject								
1	37	67	15	67	95	97	100	100
2	17	20	68	43	100	100		
3	47	30	100	100				
4	60	30	97	93	100	100		
5	42	27	83	13	100	100		

Condition 2
Random Sequence/Minimal Instructions/3-s Between-Pair-Delays
Successive Exposures

	1		2		3		4		5		6	
	Sym/	Equiv	Sym/	Equiv	Sym/	Equiv	Sym/	Equiv	Sym/	Equiv	Sym/	Equiv
Subject												
6	37	10	98	63	98	27	100	3	98	93	100	100
7	27	23	40	43	47	23	67	27	98	100		
8	42	27	100	87	100	100						
9	43	23	100	100								
10	25	37	33	33	33	30 (consistently incorrect)						

Condition 3
Random Sequence/Minimal Instructions/0.5-s Between-Pair-Delays
Exposures

	1		2		3		4		5		6	
	Sym/	Equiv	Sym/	Equiv	Sym/	Equiv	Sym/	Equiv	Sym/	Equiv	Sym/	Equiv
Subject												
11	55	27	92	57	88	43	100	100				
12	37	17	70	37	98	97						
13	28	40	68	87	85	20	77	93	97	100		
14	35	23	63	37	87	47	87	27	68	93	100	100
15	98	3	98	0 (consistently incorrect)								

inconsistency of the stimulus pairings. In Condition 4, the within-pair-delays were shorter than the between-pair delays (0.5 s and 3 s, respectively), but in Condition 5 both delays were the same (0.5 s). It was predicted that subjects in Condition 4 would produce equivalence responding (based on the differential within- and between-pair-delays), but subjects in Condition 5 would not (because both types of delays are set to the same value).

Procedure

Condition 4

Condition 4 (linear sequence of stimulus pairs/3-s between-pair-delays) was identical to Condition 2, except that the stimulus pairs were always presented in the same, fixed sequence during the training phase (A1→B1, B1→C1, A2→B2, B2→C2, A3→B3, B3→C3; see Figure 1, panel 4). The term “linear” is used to describe this sequence because the stimuli participating in each predicted equivalence relation were presented in the same A-B-C, linear-like sequence. Presenting the stimuli in this way ensures that each stimulus always appears in a consistent position in the sequence relative to the others; subjects can not, therefore, discriminate the six stimulus pairs based on the consistency versus inconsistency of the stimulus pairings. In this condition, however, it was predicted that the 3-s between-pair-delays, relative to the 0.5-s within-pair-delays, would allow the subjects to discriminate the six pairs of stimuli and therefore demonstrate equivalence responding.

Condition 5

Condition 5 (linear sequence of stimulus pairs/0.5-s between-pair-delays) was identical to Condition 4, except that the 3-s between-pair-delays were reduced to 0.5 s (Figure 1, panel 5). It was predicted that the between-pair-delays of 0.5 s, combined with the fixed linear sequence, would prevent reliable discrimination of the six stimulus pairs. For example, how might subjects discriminate reliably the B1→C1 pairing from the C1→A2 pairing if each stimulus presentation is separated by 0.5 s and the stimuli are always presented in the same fixed order (i.e., from the subjects' perspective, is C1 paired with B1 or A2)? Furthermore, if the subjects fail to

Table 2

Percent Correct on 60 Symmetry and 30 Equivalence Test Trials per Exposure

Condition 4								
Linear Sequence/Minimal Instructions/3-s Between-Pair-Delays								
Successive Exposures								
	1		2		3			
	Sym/Equiv		Sym/Equiv		Sym/Equiv			
Subject								
16	98	100						
17	27	17	100	100				
18	33	23	100	100				
19	68	7	85	90	98	97		
20	100	0 (consistently incorrect)						
Condition 5								
Linear Sequence/Minimal Instructions/0.5-s Between-Pair-Delays								
Successive Exposures								
	1		2		3		4	
	Sym/Equiv		Sym/Equiv		Sym/Equiv		Sym/Equiv	
Subject								
21	95	97	100	100				
22	80	10	95	0 (consistently incorrect)				
23	27	20	3	0	97	0 (consistently incorrect)		
24	48	0 (consistently incorrect)						
25	23	53	30	27	25	20	17	20 (inconsistent)

discriminate reliably the six stimulus pairs, it is also likely that they will fail to demonstrate reliably the formation of the predicted equivalence relations. For example, when C1 is presented as a sample with A1, A2, and A3 as comparisons, will subjects select A1 based on the A1→B1→C1 stimulus pairings, A2 based on the C1→A2 stimulus pairings, or A3 based on the C1→A2→B2→C2→A3 stimulus pairings?

Table 3

Detailed Results For Subjects Who Produced Consistently Incorrect Performances on Equivalence Tests

S 10 (Random Seq Min Instruc)	S 15 (Random Seq 0.5-s Delays)	S 20 (Linear Seq 3-s Delays)	S 22 (Linear Seq 0.5-s Delays)	S 23 (Linear Seq 0.5-s Delays)
		Symmetry Trials		
B1→A3	B1→A1	B1→A1	B1→A1	B1→A1
B2→A3	B2→A2	B2→A2	B2→A2	B2→A2
B3→A3	B3→A3	B3→A3	B3→A3	B3→A3
C1→B3	C1→B1	C1→B1	C1→B1	C1→B1
C2→B3	C2→B2	C2→B2	C2→B2	C2→B2
C3→B3	C3→B3	C3→B3	C3→B3	C3→B3
		Equivalence Trials		
C1→A3	C1→A2	C1→A2	C1→A2	C1→A2
C2→A3	C2→A3	C2→A3	C2→A3	C2→A3
C3→A3	C3→A1	C3→A1	C3→A1	C3→A1
S 24 (Linear Seq 0.5-s Delays)	S 30 (Nonlinear 3-s Delays)	S 33 (Nonlinear 0.5-s Delays)	S34 (Nonlinear 0.5-s Delays)	
		Symmetry Trials		
B1→A3	B1→A2	B1→A2	B1→A1	
B2→A3	B2→A3	B2→A3	B2→A3	
B3→A3	B3→A3	B3→A3	B3→A3	
C1→B2	C1→B1	C1→B1	C1→B1	
C2→B3	C2→B3	C2→B3	C2→B3	
C3→B1	C3→B3	C3→B3	C3→B3	
		Equivalence Trials		
C1→A2	C1→A3	C1→A2	C1→A3	
C2→A3	C2→A3	C2→A2	C2→A1	
C3→A1	C3→A1	C3→A1	C3→A2	

Results and Discussion

The percentage of correct responses on the symmetry and equivalence test trials for each individual exposure to the equivalence test for Subjects 16 to 25 is presented in Table 2 (see Figure 3 for total percentage of correct responses on the final exposure). In Condition 4 (linear sequence/3-s between-pair-delays), Subjects 16, 17, 18, and 19 produced near perfect symmetry and equivalence responding on either the first, second, or third exposure to the test. Subject 20 produced consistently incorrect responding on the first exposure. In Condition 5 (linear sequence/0.5-s between-pair-delays), Subject 21 was the only one of the five subjects to demonstrate equivalence responding (on the second exposure to the test). Subjects 22 and 23 produced near perfect symmetry responding, but did not produce any equivalence responding on their second and third exposures, respectively (i.e., consistently incorrect performances). Subject 24 was consistently incorrect on the first exposure. Subject 25 produced inconsistent responding across 4 exposures to the test, and failed to exceed 50% correct responding; hence the subject's participation in the study was terminated.

The fact that two subjects produced almost perfect symmetry but no equivalence responding in the linear/0.5-s between-pair-delays condition suggests that the stimulus pairings during this respondent training procedure may sometimes facilitate the formation of symmetry but not equivalence relations (see Table 3, Subjects 22 and 23). Inspection of Figure 1 (Condition 5) allows us to see how this might have happened. Consider, for example, the first five stimuli in the respondent training (A1→B1→B1→C1→A2). In this sequence, B1 is always paired with A1 and C1, and C1 is always paired with B1 and A2. Consequently, during a symmetry test, in which B1 is presented as a sample and A1, A2, and A3 are presented as comparisons, A1 is the only stimulus that has been paired with the sample B1. Similarly, on a symmetry test in which C1 is presented with B1, B2, and B3, B1 is the only comparison that has been paired with the sample C1. Insofar as some subjects are likely to select a comparison that was directly paired with the sample during the respondent training, symmetry responding may sometimes emerge following this procedure. Consider now, the equivalence test trial where C1 (the sample) is presented with A1, A2, and A3 (the comparisons). During the respondent training, C1 has been paired directly with A2 but not A1 (i.e., it is removed from A1 by B1). Thus, subjects may choose the directly paired A2 comparison, rather than the A1 comparison that is paired indirectly to C1 through the B1 stimulus (i.e., A1-B1-C1). (Note, however, that the symmetry *and* equivalence responding produced by Subject 21 suggests that in some instances the symmetry-facilitating effect of the linear sequence may also produce equivalence responding). In summary, therefore, symmetry responding in the absence of equivalence responding may be predicted for the linear/0.5-s between-pair-delays condition, if we accept that some subjects are likely to match comparisons to samples that were directly paired during the respondent training. The next experiment was designed to examine this issue.

Experiment 3

Experiment 3 consisted of Conditions 6 and 7. In both of these conditions, the fixed linear sequence employed in Experiment 2 was modified so that the stimuli were presented in a fixed *nonlinear* sequence (i.e., A1→B1, A2→B2, A3→B3, B1→C1, B2→C2, B3→C3). The term "nonlinear" is used to describe this sequence because the A and B stimuli participating in each of the predicted equivalence relations were presented before the B and C stimuli from each of the predicted relations. The nonlinear sequence training ensured that on four of the six tasks that tested for symmetry responding, two of the comparison stimuli (one "correct" and the other "incorrect") had been directly paired, during training, with the sample stimulus (e.g., B1 was directly paired with A1 and A2). In effect, either comparison was equally correct based on direct pairing. It was predicted, therefore, that reliable symmetry responding, in the absence of equivalence responding, would not occur with any subject using the nonlinear training procedure.

In Condition 6, the within-pair-delays were shorter than the between-pair delays (0.5 s and 3 s, respectively), but in Condition 7 both delays were the same (0.5 s). It was predicted that subjects in Condition 6 would produce equivalence responding (based on the differential within- and between-pair-delays), but subjects in Condition 7 would not (because both types of delays are set to the same value). Furthermore, subjects in Condition 7 should produce neither symmetry nor equivalence responding.

Procedure

Condition 6

Condition 6 (nonlinear sequence of stimulus pairs/3-s between-pair-delays) was identical to Condition 4, except that the stimulus pairs were always presented in the same nonlinear sequence during the respondent training procedure (i.e., A1→B1, A2→B2, A3→B3, B1→C1, B2→C2, B3→C3; see Figure 1, panel 6). Presenting the stimuli in this way ensured that each stimulus always appeared in a consistent position in the sequence relative to the others, and thus, as in the previous experiment, the subjects could not discriminate the six stimulus pairs based on the consistency verses inconsistency of the stimulus pairings. Although Condition 6 employed a fixed, nonlinear sequence, it also used 3-s between-pair-delays. Consequently, it was predicted that these delays, relative to the 0.5-s within-pair-delays, would allow the subjects to discriminate the six stimulus pairs and therefore demonstrate equivalence responding.

Condition 7

Condition 7 (nonlinear sequence of stimulus pairs/0.5-s between-pair-delays) was identical to Condition 6, except that the between-pair-delays of 3 s were reduced to 0.5 s (Figure 1, panel 7). It was predicted that the 0.5-s between-pair-delays *combined* with the nonlinear sequence would prevent the "symmetry facilitating effect" of Condition 5. Consider, for example, the first five stimuli in the nonlinear sequence (i.e., A1→B1→A2→B2→A3). In this sequence, B1 is directly paired with both A1 and A2, and thus during a symmetry test in which B1 is presented as a sample with A1, A2, and A3 as comparisons, *both A1 and A2 are equally likely choices* if a subject simply selects the comparison that was directly paired with the sample during respondent training.

Table 4

Percent Correct on 60 Symmetry and 30 Equivalence Test Trials per Exposure

Condition 6: Nonlinear Sequence/Minimal Instructions/3-s Between-Pair-Delays						
	Successive Exposures					
	1		2		3	
	Sym/Equiv		Sym/Equiv		Sym/Equiv	
Subject						
26	97	97	100	100		
27	52	47	68	43	97	100
28	83	97	92	90	100	97
29	80	83	100	100		
30	10	17	48	0	52	0 (Consistently incorrect)

Condition 7: Nonlinear Sequence/Minimal Instructions/0.5-s Between-Pain-Delays								
Successive Exposures								
	1		2		3		4	
	Sym/Equiv		Sym/Equiv		Sym/Equiv		Sym/Equiv	
Subject								
31	52	10	50	17	52	33	35	33 (inconsistent)
32	38	33	45	3	62	27	52	10 (inconsistent)
33	35	3	47	37	50	30 (consistently incorrect)		
34	60	0	65	53 (consistently incorrect)				
35	42	13	35	27	18	20	28	33 (inconsistent)

Results and Discussion

The percentage of correct responses on the symmetry and equivalence test trials for each individual exposure to the equivalence test for Subjects 26 to 35 is presented in Table 4 (see Figure 3 for total percentage of correct responses on the final exposure). In Condition 6, Subjects 26 and 29 produced perfect symmetry and equivalence responding on their second exposures, and Subjects 27 and 28 were almost perfect on their third exposures. Subject 30 produced a consistently incorrect performance on the third exposure. In Condition 7, Subjects 31, 32, and 35 produced inconsistent (and below 50% correct) responding, and their participation was terminated after their fourth exposures, in accordance with the consistency criterion. Subjects 33 and 34 were consistently incorrect on their third and second exposures respectively, and neither of these subjects produced symmetrical responding (see Table 3). As predicted, therefore, the "symmetry generating effect" of the linear/0.5-s between-pair-delays condition was absent in the nonlinear/0.5-s between-pair-delays condition.

General Discussion

The current study clearly demonstrates that it is possible to produce equivalence responding in adult human subjects using a respondent training procedure. Furthermore, it was shown that the effectiveness of the respondent procedure in producing equivalence is dependent upon (a) the presence of longer between-pair-delays relative to the within-pair-delays and (b) the sequence in which the stimulus pairs are presented. Subjects produced equivalence responding after the random sequencing of stimulus pairs, both with and without detailed instructions (Conditions 1 and 2). Interestingly, when the 3-s between-pair-delay was reduced to 0.5 s, subjects continued to produce equivalence. This finding suggested that the consistency versus inconsistency of stimulus pairing during the random sequencing produced the appropriate discriminations between stimulus pairs (in the absence of the 3-s between-pair-delays) necessary for the formation of equivalence relations. Evidence for this was produced in Experiments 2 and 3 in which most subjects formed equivalence relations when provided with 3-s between-pair-delays, but failed when these delays were reduced to 0.5 s (i.e., the *fixed* linear and nonlinear sequences prevented the appropriate discriminations between stimulus pairs and thus the formation of equivalence relations observed in the random sequencing conditions).

An interesting issue arising from this study is that the majority of subjects exposed to the respondent training procedure produced symmetry and equivalence responding (i.e., excluding the fixed-sequence, "control" Conditions 5 and 7, 21 out of 25 subjects produced equivalence). This represents an 84% success rate, which compares favorably with the standard matching-to-sample training procedure. For example, Wulfert, Dougher, and Greenway (1991, Experiment 1) reported that 24 out of 29 subjects exposed to a standard matching-to-sample training procedure produced equivalence responding on a subsequent test (i.e., 82.7% success rate). Of course, comparing across studies from different laboratories in this manner can only ever be suggestive, and thus future research will need to compare systematically the respondent training procedure with traditional matching-to-sample training.

A related issue concerns the fact that most of the subjects required repeated exposures to the training and testing (i.e., only one subject produced equivalence responding on the first exposure to the test). In other words, subjects required at least two exposures to the training *and* testing stages before equivalence responding emerged. These data indicate that for the majority of the subjects, respondent training alone was necessary, but not sufficient, to produce equivalence responding. Interestingly, a number of equivalence studies that have used matching-to-sample training procedures have reported similar effects (e.g., Cullinan, Barnes, Hampson, & Lyddy, 1994; Dymond & Barnes, 1994; Saunders, K. J., et al., 1993). In a very recent study, however, the need for repeated training and testing was significantly reduced by using a simple-to-complex protocol, in which subjects were trained and tested for symmetry relations, before being trained and tested for more complex relations (i.e., transitivity, and combined symmetry and transitivity) (Fields, Adams, Newman, & Verhave, 1992). Within the context of the current study, the gradual emergence of the predicted performances may have been related to the fact that subjects were trained and then tested for symmetry and combined symmetry and transitivity responding within single blocks. Perhaps, therefore, equivalence would have emerged far more rapidly in the present study, if subjects had been respondently trained on the three A-B tasks and tested for B-A symmetry; then trained on the B-C tasks and tested for C-B symmetry; then tested for A-C transitivity; and then finally tested for C-A combined symmetry and transitivity. Future studies in this area should certainly examine this possibility.

Perhaps the most remarkable feature of the current study is that explicit, differential reinforcement was not provided for selecting any of the stimuli in a matching-to-sample context before the equivalence test. Previous research has shown that mentally retarded individuals and normally developing children may demonstrate the merger and development of equivalence relations by unreinforced conditional selection of comparison stimuli *following a history of explicitly reinforced matching-to-sample responding and successful equivalence testing* (Saunders, R. R., Saunders, K. J., Kirby, & Spradlin, 1988; Williams, Saunders, K. J., Saunders, R. R., & Spradlin, 1995). In the R. R. Saunders et al. study, for example, following the formation of equivalence relations subjects were allowed to choose (in the absence of differential reinforcement) which novel comparisons "went with" the previously trained samples, and having done so they consistently related these novel comparisons in a 'relation-consistent-manner' to the remaining stimuli participating in the previously established equivalence relations. The procedures of the current study, however, demonstrated reliable equivalence responding without an experimental history of explicit differential reinforcement for matching-to-sample responding, and without an experimental history of successful equivalence testing (furthermore, in all but one condition, only minimal instructions were provided). These data may have important implications for empirical and conceptual analyses of stimulus equivalence.

At an empirical level, for example, it remains to be seen whether respondent training will produce equivalence responding in young or mentally retarded subjects. Of course, the current procedure might have to be simplified for these populations. For example, a subject could be respondently trained using one stimulus pair, A1-B1, and then tested repeatedly using a single matching-to-sample task (i.e., present B1 as sample with A1, A2, and A3 as comparisons); the next stimulus pair could then be trained and tested in a similar manner, and so on, until all equivalence relations had been formed. If mentally young individuals readily show equivalence using this simplified respondent training, it would suggest that traditional matching-to-sample training is perhaps an "overly complicated" procedure for generating equivalence responding in human populations. Alternatively, imagine that mentally young subjects, who would be expected to produce equivalence responding using the standard matching-to-sample training and testing procedure (e.g., Barnes et al., 1990; Barnes, Browne, Smeets, & Roche, 1995; Devany et al., 1986; Eikeseth & Smith, 1992), failed to demonstrate equivalence using the simplified respondent training method. Such a result would suggest that certain features of the matching-to-sample procedure itself provide important controlling variables over the emergence of equivalence relations. Further studies that modified the respondent training procedure (e.g., by introducing an observation response, or an operant requirement similar to that used in configural conditioning experiments; see Sutherland & Rudy, 1989) might then identify exactly what features of matching-to-sample are critical for the formation of equivalence relations in mentally young, human populations. In summary, by exploring different procedures for producing or failing to produce equivalence in different subject populations it should be possible to identify the important variables involved in equivalence responding. The present study represents an important step in this direction.

At a conceptual level, the current data raise some interesting issues concerning the nature of stimulus equivalence itself. Why, for example, did the respondent training procedure produce equivalence responding in the absence of differential reinforcement for the baseline conditional discriminations? One possible answer to this question is provided by relational frame theory (RFT).[2] According to RFT, emergent performances such as equivalence are normally produced, in part, by the subject's history of arbitrarily applicable relational responding that is brought to bear by various contextual cues on the matching-to-sample test (see Barnes, 1994; Barnes, 1996; Barnes & Holmes, 1991; Barnes & Roche, 1996; Hayes, S. C., 1991, 1994; Hayes, S. C., & Hayes, L. J., 1989). From this perspective, learning to name objects and events in the world represents one of the earliest and most important forms of arbitrarily applicable relational responding. For instance, parents often utter the name of an object in the presence of their young child and then reinforce any orienting response that occurs towards the named object. This interaction may be described as, hear name A → look at object B. Parents also often present an object to their young child and then model and reinforce an appropriate "tact" (Skinner, 1957). This interaction may be described as see object B → hear and say name A (see Barnes, 1994, for a detailed discussion). Initially each interaction may require explicit reinforcement for it to become firmly established in the behavioral repertoire of the child, but after a number of exemplars have been trained, derived "naming" may be possible. Suppose, for example, a child with this naming history is told "This is your shoe." Contextual cues, such as the word "is" and the naming context more generally, may establish symmetrical responding between the name and the object. Without further training, for example, the child will now point to the shoe when asked "Where is your shoe?" (name A → object B) *and* will utter "shoe" when presented with the shoe and asked "What is this?" (object B → name A).

[2]The reader is referred to Sidman (1994) and to Stromer et al. (1993) for two different perspectives on stimulus equivalence. Barnes and Roche (1996) provide a detailed discussion of these two perspectives in relation to RFT.

Arbitrarily applicable relational responding may be brought to bear on any stimuli, given appropriate contextual cues. RFT therefore explains equivalence responding in terms of a training history applicable to a given situation. In effect, when a young child is taught a number name-object and object-name relations and is then exposed to a matching-to-sample procedure, contextual cues provided by this procedure may be discriminative for equivalence responding. In fact, the matching-to-sample format itself may be a particularly powerful contextual cue for equivalence responding insofar as it is often used in preschool education exercises to teach picture-to-word equivalences (see Barnes, 1994, and Barnes & Roche, 1996, for detailed discussions).

How then might RFT account for the current data? To answer this question, consider the following. In addition to naming, children are normally taught that events that are correlated in time and/or space often "go together" (i.e., participate in equivalence relations). In a typical early education exercise, for example, a child might learn that a picture of a dark cloud and the words "dark cloud" should be matched to a picture of rain and to the word "rain." In effect, the temporal and spatial correlation of actual dark clouds and rain is used to establish, in certain contexts, an equivalence relation between these events and the arbitrary stimuli "dark cloud" and "rain." After sufficient training of this type, a child might respond, in certain contexts, to other correlated events as participating in equivalence relations without explicit reinforcement for doing so. For example, having established an equivalence relation between actual lightning and the word "lightning" and another equivalence relation between actual thunder and the word "thunder," given an appropriate context (e.g., when asked by a teacher about different types of weather), the child might say "thunder and lightning go together." In effect, the correlation between lightning and thunder in the natural environment is sufficient to establish an equivalence relation between these events and their descriptors if (a) the child has an appropriate history of arbitrarily applicable relational responding and (b) is provided with an appropriate context (i.e., a question about types of weather from a teacher).

From the RFT perspective, therefore, the temporal correlations that occurred among the stimuli during the respondent training produced equivalence responding in the current study, in part, because (a) the adult subjects all possessed the appropriate histories of arbitrarily applicable relational responding and (b) these histories were brought to bear by various contextual cues provided by the experimental setting and procedure. At the present time, of course, it is not possible to identify exactly what properties of the experimental environment functioned as contextual cues, but a likely source of contextual control for equivalence responding in the current study was the matching-to-sample format of the equivalence test itself (see two paragraphs above, and see Barnes, 1994; Barnes & Roche, 1996). More informally, exposure to the matching-to-sample tasks may have helped subjects to discriminate that the respondent training was being used to "*tell* them which stimuli go together," and that the matching-to-sample tasks were being used to determine whether they had "*learned* which stimuli go together." This RFT interpretation would certainly explain why almost all of the subjects required at least two exposures to the training and testing before demonstrating equivalence. That is, only after a subject had been exposed to the matching-to-sample test did the respondent training then begin to function as the baseline training for equivalence responding. One interesting follow-up study, therefore, might be to establish equivalence responding in a group of subjects using the respondent training, and then repeat the procedure with novel stimuli. If exposure to the equivalence test using the first set of stimuli was functioning as an important contextual cue for equivalence, we would expect most subjects to demonstrate more rapid emergence of equivalence responding with the second set of stimuli than with the first. Research is currently underway in our laboratories to address this and related issues.

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